METHOD AND APPARATUS OF NOISE VARIANCE ESTIMATION FOR USE IN WIRELESS COMMUNICATION SYSTEMS

Field of the Invention

The present invention relates generally to a method and apparatus of noise variance estimation for use in wireless communication systems, and more particularly, to a method and apparatus of noise variance estimation by exploiting the training sequence.

Background of the Invention

CDMA (Code Division Multiple Access) is a new wireless communication technology developed after FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access). In CDMA wireless communication, different UEs (user equipments) are allocated with different orthogonal spreading codes, and signals spread by different UEs with different spreading codes can be transferred on the same frequency band.

A CDMA downlink transmission model is put forward in the paper entitled "Data Detection Algorithms Specially Designed For The Downlink of CDMA Mobile Radio Systems", VTC, 1997, by A. Klein, as shown in Fig.1. In order to transmit signal vectors $\underline{d}^{(1)}, \ldots, \underline{d}^{(k)}, \ldots, \underline{d}^{(K)}$ (wherein $\underline{d}^{(k)}$ (k=1...K) is composed of N complex components) to UE1, ..., UEk, ...UEK respectively, base station 200 first spreads signal vectors $\underline{d}^{(1)}, \ldots, \underline{d}^{(k)}, \ldots, \underline{d}^{(K)}$ by exploiting spreading codes $\underline{c}_d^{(1)}, \ldots, \underline{c}_d^{(k)}, \ldots, \underline{c}_d^{(K)}$ allocated to UE1, ..., UEk, ..., UEK, then combines the spread signal vectors into signal vector $\underline{s}_d$ and transmits it to each corresponding UE 220 via the same channel 210. Assumed that signal vector $\underline{s}_d$ reaches UEκ (κ=1...K) through multiple propagation paths and the CIR (channel impulse response) of each

propagation channel is $\underline{h}_{d(i)}^{(K)}$ (i=1、2、...), signal vector $\underline{e}_d^{(K)}$ received by UEK can be expressed by equation (1) as follows:

$$\underline{e}_d^{(K)}=\underline{H}_d^{(K)}\underline{C}_d\underline{d}+\underline{n}_d^{(K)}=\underline{H}_d^{(K)}\underline{s}_d+\underline{n}_d^{(K)} \qquad (1)$$

wherein $\underline{H}_d^{(K)}$ is the CIR matrix constructed with the CIR $\underline{h}_{d(i)}^{(K)}$ (i=1、2、...) of each propagation channel, $\underline{C}_d$ is the spreading code matrix constructed with spreading codes $\underline{c}_d^{(1)}$, ..., $\underline{c}_d^{(k)}$, ..., $\underline{c}_d^{(K)}$ (as to the construction methods of $\underline{H}_d^{(K)}$ and $\underline{C}_d$, referring to the above paper by A. Klein), $\underline{d}=(\underline{d}^{(1)T}, \ldots, \underline{d}^{(k)T}, \ldots, \underline{d}^{(K)T})^T$, $[.]^T$ represents matrix transposition, $\underline{s}_d$ represents the obtained signal vector after $\underline{d}$ is spread and combined, $\underline{s}_d=\underline{C}_d\underline{d}$, and $\underline{n}_d^{(K)}$ is the noise vector.

Equation (1) indicates that the receiv ed signal vector $\underline{e}_d^{(K)}$ contains UEk's desired signal vector $\underline{d}^{(K)}$, as well as signal vectors sent to other UEs by the base station and the noise vector.

To help UEK to obtain its desired signal vector $\underline{d}^{(K)}$ from the received signal vector $\underline{e}_d^{(K)}$ with the mini mum error, many method for signal reception have been presented, which can be referred to "Iterative Multiuser Receiver /Decoders With Enhanced variance Estimation", VTC, 1999, by Kimmo Kettunen, and "Zero Forcing an Mininum Mean -Square-Error Equalization for Multiuser Detection in Code -Division multiple-access channels", IEEE Transactions on Vehicular Technology, vol.45, pp.276 -287, May 1996, by A. Klein. But these methods for signal reception all rely heavily on the channel information, or namely noise va riance, to obtain the desired signal vector from the received signal vector, and thus the noise variance needs to be computed precisely to obtain the desired signal vector with minimum error.

To get an accurate noise variance, various noise estimation meth ods have been put forward. For example, a conventional variance estimation technique for use in AWGN channel is raised in "A novel variance estimator for turbo-code decoding", Proc. Of ITC'97, pp173 -178, April 1997, by M. Reed and J. Asenstorfer; a Rake technique for alleviating multipath

interference is put forward in US.PAT US200220110199, entitled "Method for Noise Energy Estimation in TDMA Systems ". Additionally, there are some noise estimation methods in which noise variance is computed by convolving the training sequence. These noise estimation methods can meet the precision requirement of 2G wireless communication systems.

But in 3G wireless communication systems, more accurate noise variance is needed for signal reception, for example, the key technologies of multiuser detection and turbo -code both have high requirement for accurate noise variance. Current noise estimation methods can 't satisfy the precision requirement for noise variance of 3G wireless communication systems.

Summary of the Invention

An object of the present invention is to provide a method and apparatus of noise variance estimation for use in wireless communication systems, in which the training sequence is exploited to compute noise variance to obtain more accurate noise variance.

A method of noise variance estimation is proposed in the present invention for use in wireless communication systems, comprising steps of: receiving a signal vector containing training sequence and noise vector transmitted via at least one propagation path from the base station; estimating, according to the signal vector, the channel impulse response of each propagation path to construct a channel impulse response matrix; calculating the noise variance of the signal vector according to the channel impulse response matrix and the signal vector if the channel impulse response remains primarily unchanged during the special time duration of the training sequence.

Brief Description of the Drawings

Fig.1 illustrates conventional CDMA downlink transmission model;

Fig.2 is a flow chart illustrating the noise variance estimation method in the present invention;

Fig.3 is a block diagram illustrating the UE equipped with the noise variance estimation apparatus in an embodiment of the present invention;

Fig.4 is a block diagram illustrating the noise variance estimation apparatus in an embodiment of the present invention.

Detailed Description of the Invention

TD-SCDMA will be exemplified in the following to describe an embodiment of the present invention in detail.

In TD-SCDMA, the base station transmits signal vector to each UE in corresponding timeslot. According to the timeslot format of TD -SCDMA, the signal vector sent to each UE by the base station in corresponding timeslot is composed of the training sequence and the s pread user signal.

With regard to the UEs allocated in the same timeslot, the base station first combines the signal vectors to be transmitted to each UE into a combined signal vector, and then transmits this combined signal vector in the timeslot to each UE. Said combined signal vector is also composed of user signal and training sequence, wherein the user signal in the combined signal vector is obtained by combining the spread user signal in the signal vector to be transmitted to each UE, and the training sequence in the combined signal vector is obtained by combing the training sequence in the signal vector to be transmitted to each UE.

The training sequence allocated to each UE in a cell is obtained through performing different shift operation on the sam e basic training sequence, so the training sequence of the combined signal vector can be considered as the basic training sequence. Each UE has acquired the basic training sequence used by its cell during cell search procedure, so the training sequence sent by the base station in the timeslot is known beforehand to each UE.

Let's suppose that the training sequence included in the signal vector sent by the base station in a timeslot reaches a UE through at least one propagation path, the signal vector receiv ed by the UE in the timeslot is r,

composed of said training sequence and noise vector n, and the known value of said training sequence is s. According to equation (1), signal vector r can be expressed as follows:

$$r = Hs + n \qquad (2)$$

wherein H is the CIR matrix constructed by the CIR of each propagation path between the UE and the base station.

According to the channel estimation method as described in "Low Cost Channel Estimation in the uplin k receiver of CDMA mobile radio systems", Frequenz, vol.47, pp.292 -298, Nov./Dec. 1993, by B. Steiner and P.W.Baier, the maximum likelihood estimated value $\hat{\mathbf{s}}$ of the training sequence included in signal vector r can be expressed as fol lows:

$$\hat{\mathbf{s}}=(\mathbf{H}^H\mathbf{H})^{-1}\mathbf{H}^H\mathbf{r}=\mathbf{s}+(\mathbf{H}^H\mathbf{H})^{-1}\mathbf{H}^H\mathbf{n}=\mathbf{s}+\mathbf{n}' \qquad (3)$$

wherein superscript ^{H} represents complex conjugate transposition.

From equation (3), according to the known value s of the training sequence contained in signal vector r, the estimated value n ′ of noise vector n can be given by:

$$\mathbf{n}'=\hat{\mathbf{s}}-\mathbf{s}=(\mathbf{H}^H\mathbf{H})^{-1}\mathbf{H}^H\mathbf{n} \qquad (4)$$

With the covariance matrix being:

$$\begin{aligned} E\{\mathbf{n}'\mathbf{n}'^H\} &= E\{(\mathbf{H}^H\mathbf{H})^{-1}\mathbf{H}^H\mathbf{n}\cdot\mathbf{n}^H\mathbf{H}(\mathbf{H}^H\mathbf{H})^{-1}\} \\ &= (\mathbf{H}^H\mathbf{H})^{-1}\mathbf{H}^H E(\mathbf{n}\mathbf{n}^H)\mathbf{H}(\mathbf{H}^H\mathbf{H})^{-1}\} \\ &= \sigma^2(\mathbf{H}^H\mathbf{H})^{-1} \qquad (5) \end{aligned}$$

wherein E{.} denotes expectation operation. By carrying out the operation of matrix trace between the two sides of above equation (5), it is easy to come down to following formulation computing the average variance $\overline{\sigma}_{n'}^2$ of the estimated value $\mathbf{n}'$ of the noise vector n:

$$\overline{\sigma}_{n'}^2 = \sigma^2 \cdot trace\{(\mathbf{H}^H\mathbf{H})^{-1}\}/N \qquad (6)$$

wherein N is the chip duration of the training sequence, operator *trace* (·) means the computation of a matrix trace, σ^2 is the noise variance of

the signal vector r.

If $\bar{\sigma}_n^2$ is computed with conventional methods, it will be very complicated. In fact, the computation of variance $\bar{\sigma}_n^2$ can be approximated by calculating the mean squared value of all elements about the estimated value $\mathbf{n}'$ of the noise vector n located in one training sequence time duration if the channel could be regarded as constant at that time. The noise variance σ^2 of the signal vector r can now be deduced as :

$$\sigma^2 \approx (\mathbf{n}'^H \mathbf{n}') / trace\{(\mathbf{H}^H \mathbf{H})^{-1}\} \qquad (7)$$

To further improve the estimation performance, we can sum and average the noise variance σ^2 calculated from equation (7) in the timeslot and the noise variance σ^2 calculated from equation (7) in each previous timeslot, and take the mean of different σ_i^2 as the noise variance σ^2 of signal vector r in the timeslot.

The above section describes the principle of computing noise variance by exploiting training sequence in the present invention.

The following section will describe the proposed noise variance estimation method in detail, in conjunction with Fig.2.

First, the UE receives a signal vector containing training sequence and noise vector in a timeslot transferred through at least one propagation path from the base station (step S10).

Secondly, the UE estimates the CIR of each propagation path according to the received signal vector, and constructs a CIR matrix H by using the estimated CIR of each propagation path (step S20).

Thirdly, the UE estimates the maximum likelihood estimated value $\hat{\mathbf{s}}$ of the training sequence included in said signal vector using equation (3), according to said signal vector and said CIR matrix (step S30).

Fourthly, the UE computes the estimated value n ′ of the noise vector contained in said signal vector by using equation (4), according to the MLE

(maximum likelihood estimate) value $\hat{s}$ of the training sequence included in said signal vector and the known value of the training sequence (step S40). Wherein, the known value of the training sequence contained in said signal vector is acquired by the UE in cell search procedure.

Fifthly, the UE computes the noise variance σ^2 of said signal vector by using equation (7), according to the estimated value n ′ of the noise vector contained in said signal vector and said CIR matrix H (step S50). Wherein first the power p_n^2 of n′ can be computed according to equation $p_n^2=(n')^H(n')$; then the trace cf of matrix $((H^H H)$ can be computed, that is cf= *trace* $((H^H H)^{-1})$; lastly, the noise variance σ^2 can be computed according to equation $\sigma^2 = p_n^2/cf$, that is ,equation (7).

Lastly, the UE sums and averages the noise variance σ^2 calculated from equation (7) in the timeslot and the noise variance σ^2 calculated from equation (7) in each previous timeslot, and takes the mean of different σ_i^2 as the noise variance σ^2 of signal vector r in the timeslot (step S60).

A detailed description will be given below to the proposed noise variance estimation apparatus, in conjunction with Fig.3 and Fig.4.

Fig.3 is a block diagram illustrating the UE equipped with the proposed noise variance estimation apparatus. As Fig.3 shows, in cell search procedure before the UE communicates with the base station, cell searching means 40 acquires the basic training sequence s used by the cell where the UE is camping. When the UE communicates with the base station, the antenna of the UE first sends the sign al vector Rx received in a timeslot to multiplier 10, and multiplier 10 multiplies the received signal vector Rx by the RF carrier generated by VCO 20, to convert signal vector Rx into baseband signal vector. Then, ADC 30 converts the baseband signal vecto r outputted from multiplier 10 into digital baseband signal vector r. Afterwards, cell searching means 40 synchronizes the digital baseband signal vector r outputted from ADC 30, and channel estimating means 50 computes the CIR

of each propagation channel for the synchronized digital baseband signal vector r by using conventional channel estimation methods, and constructs CIR matrix with the computed CIR of each propagation path. Next, noise variance estimating means 60 computes the noise variance of the di gital baseband signal vector r according to the CIR matrix computed by channel estimating means 50, the digital baseband signal vector r outputted by ADC 30 and the basic training sequence s acquired by cell searching means 40. Finally, data detecting mean s 70 acquires the desired user signal from the digital baseband signal vector r according to the noise variance computed by noise variance estimating means 60, by using conventional data detection methods, such as multiuser detection method, turbo -code decoding and etc.

Fig.4 is a block diagram illustrating noise variance estimating means 60. Referring to Fig.4, noise variance estimating means 60 comprises:

equalizing means 601, for estimating the MLE value $\hat{s}$ of the training sequence contained in said digital baseband signal vector r according to the CIR matrix H computed by channel estimating means 50 and the digital baseband signal vector r outputted by ADC 30, by using equation (3);

noise estimating means 602, for calculating the est imated value n′ of the noise vector contained in said digital baseband signal vector r according to the MLE value $\hat{s}$ of the training sequence contained in said digital baseband signal vector r computed by equalizing means 601, and the basic training sequence s (or namely the known value of the training sequence contained in said digital baseband signal vector r), by using equation (4);

noise power calculating means 603, for calculating the power p_n^2 of the estimated value n′ of said noise vector acco rding to the estimated value n′ of the noise vector contained in said digital baseband signal vector r computed by noise estimating means 602, by using equation $p_n^2=(n')^H(n')$;

equalization revising means 604, for computing the trace cf of matrix $((H^H H)^{-1})$, that is cf=$trace((H^H H)^{-1})$;

noise power revising means 605, for calculating the noise variance σ^2

according to the power p_n^2 of the estimated value n' of said noise vector calculated by noise power computing means 603 and the trace cf computed by equalization revising means 604, by using equation $\sigma^2 = p_n^2/cf$.

Beneficial Results of the Invention

As described above, in the proposed noise variance estimation method and apparatus for use in wireless communication systems, training sequence is used to compute the noise variance, so the computed noise variance can meet the requirement for higher accuracy.

It is to be understood by those skilled in the art that the method and apparatus of noise variance estimation for use in wireless communication systems as disclosed in this invention can be modified considerably without departing from the spirit and scope of the invention as defined by the appended claims.